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for Research Supported by the
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Title: Interfacial Viscosity Measurements of
Adsorbed Monolayers on Metal Surfaces

PI: Jacqueline Krim
Physics Department, Northeastern University
Boston, MA 02115
(617) 437-2926

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Scientific Officer: Richard G. Brandt, Physics Division

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I. Scientific Progress Summary and Student Support

At this writing, the ONR award has been in effect for one year. During this period, two graduate students have been partially supported: Jean Digel and Ronald Chiarello.

Digel, an incoming graduate student, carried out the construction of a second deposition system and improvements on one of our existing gas adsorption systems. Upon completion of this work, she investigated the slipping behavior of several model liquid films adsorbed on silver and gold substrates. This work, presented at the most recent AVS meeting, provided us with an initial survey of the types of behavior which we will be encountering throughout the course of our investigations. Digel's work has also demonstrated a general trend among monolayers: the lighter molecular weight films appear to slip for longer characteristic times.

Chiarello, a more advanced student, carried out studies of the interfacial viscosity of xenon and krypton films on Au(111). Our particular interest here was to map out temperature dependencies of the interfacial viscosities (sometimes referred to as coefficients of sliding friction) in order to allow future comparison with theory. Chiarello has also carried out an initial study of the dependence of the sliding friction on the amplitude of vibration of the oscillator which is the substrate for the adsorbed film. The interfacial viscosity deduced from our measurements is observed to increase with increasing oscillator amplitude (Figure 1). This result is consistent with a frictional force described by $F = -\beta v^2$, where v is the velocity of the film with respect to the substrate. We are currently preparing a manuscript which describes these results for submission to Physical Review Letters.

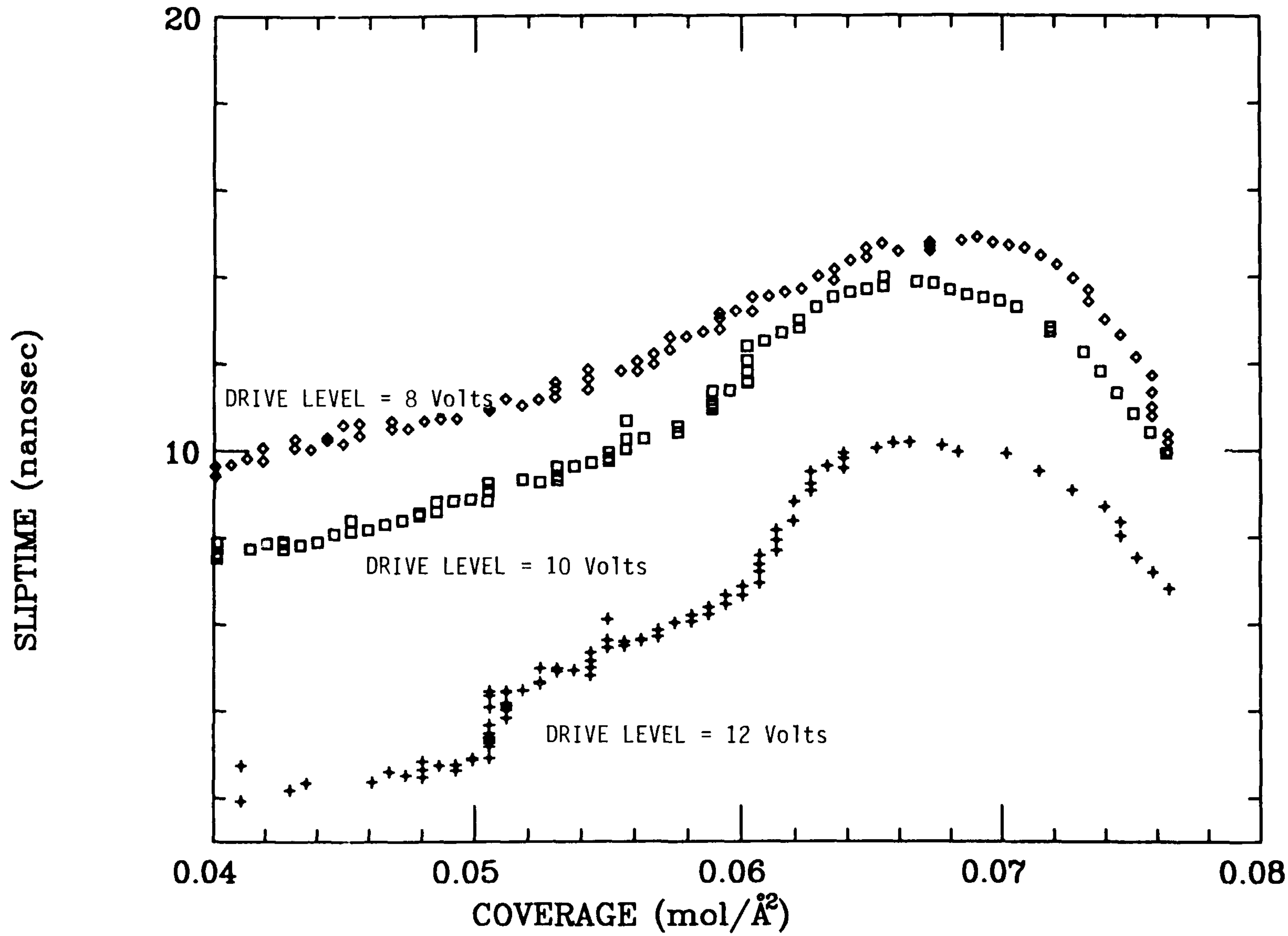

Figure 1. Average film sliptime of Krypton/Au at 77.4 K versus film coverage in atoms/square angstrom for three different substrate drive levels. The decreased sliptimes at higher drive levels is consistent with a frictional force law of the form $F = -Bv^2$, where B is a constant and v is the velocity of the film with respect to the substrate.

II. New Developments

(1) Alan Widom, a theorist at Northeastern University who has taken an interest in these studies, has worked out a relation between the interfacial viscosity of the film and its spreading diffusion rate. This is a quantity which describes the collective behavior of the film. Naturally, films which slip more on the surface also exhibit greater spreading rates. This work is currently being written up.

(2) Mark Robbins, a theorist at John Hopkins University in Baltimore has carried out computer simulations of the effects on varying the film-substrate van der Waals interactions on liquid slippage at a solid wall. His work is currently in press. It appears quite feasible for computer simulations to treat the precise experimental systems which we are currently studying.

(3) We have obtained equipment support from NSF (for studies of surface fractals), which should allow purchase of a scanning tunneling microscope in the upcoming year. In addition to the obvious benefits towards our studies of surface fractals, this should allow us to be able to cross-reference the slippage behavior of our films with microscopic details of the substrate.

III. Summary of Upcoming Work

In the upcoming year, we plan to embark on two general areas of research. The first is a comparative study of the role of the film-substrate van der Waals interaction in determining film slippage effects. We are hopeful that computer simulations will be available upon the completion of our studies to provide comparison with the experimental results. The second area of research will be a comparative study of cyclohexane, benzene and pyridine adsorbed on silver. This will allow us a systematic study of the effect of film structure on slippage.

IV. Invited Talks on Research Supported by this ONR grant:

(1) "Sliding Friction of an Adsorbed Monolayer", colloquium presented at the University of California, Santa Barbara; April 17, 1990

(2) "Sliding Friction Measurements of Physisorbed Monolayers", invited paper to be presented at "Surface Physics in Materials Science", to be held at the University of Texas at El Paso M.R.C.E. on June 4, 1990

(3) "Probing Phase Transitions and Surface Melting through Measurements of Interfacial Viscosity", invited talk to be presented at "Phase Transitions in Surface Films", a NATO Advanced Study Institute to be held at the Ettore Majorana Center, Erice, Italy during June 19-30.

V. Contributed Talks on Research Supported by this ONR grant:

(1) "Slippage of Simple Liquid Monolayers Adsorbed on Silver and Gold Substrates", J. Krim, E.T. Watts and J. Digel, American Vacuum Society Topical Conference on "Nanometer Scale Properties of Surfaces and Interfaces"; Boston, October 1989

(2) "Measurement of the Spreading Diffusion Coefficient of an Adsorbed Monolayer by means of a Quartz Crystal Oscillator", A. Widom and J. Krim, American Physical Society, March 1990, Anaheim, CA

(3) "Interfacial Viscosity Studies of the Melting of Xenon Monolayers", J. Krim and R. Chiarello, American Physical Society, March 1990, Anaheim, CA

VI. Publications Acknowledging Support by this ONR grant:

(1) "Slippage of Simple Liquid Monolayers Adsorbed on Silver and Gold Substrates", J. Krim, E.T. Watts and J. Digel, J. Vac. Sci. Tech. A, (1990) in press

(2) "Probing Phase Transitions and Surface Melting through Measurements of Interfacial Viscosity", J. Krim, book chapter written for "Phase Transitions in Surface Films", H. Taub, editor (Plenum Press, New York, 1991)

(3) "Melting of Molecularly Thin Xenon and Krypton Films Studied through Measurements of Interfacial Viscosity", J. Krim and R. Chiarello, (manuscript in preparation)

(4) "Surface Diffusion of an Adsorbed Layer Probed by a Quartz Crystal Oscillator", A. Widom and J. Krim (manuscript in preparation)